

Toxic effects of neonicotinoid insecticides on nymphs and adults of the sunn pest, *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae)

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Abstract: *Eurygaster integriceps* is a key pest of wheat and barley in Iran. Neonicotinoid insecticides, a strong group of insecticides, have good effect on sucking pests. In this study, effects of four neonicotinoids (thiamethoxam, imidacloprid, dinotefuran and acetamiprid) on 3rd nymphs and adults of *E. integriceps* via two methods (contact and chemigation) were investigated. Although tested insecticides had no strong effect on *E. integriceps* in contact method and acceptable mortality was seen at very high concentration (5 000 mg/L a. i.), all insecticides had acceptable toxicity to nymphs and adults through chemigation bioassay. According to current results, using chemigation can be a novel method for management of this important pest.

Key words: Sunn pest (*Eurygaster integriceps*); neonicotinoids; toxicity; contact toxicity; chemigation; sucking pests

1 INTRODUCTION

The sunn pest, *Eurygaster integriceps* Puton (Hemiptera: Scutelleridae), is a key pest of wheat and barley in the Palearctic Region, Near and Middle East, Eastern and Southern Europe and North Africa. Approximately, over 15 million hectare of wheat and barley fields are infected during outbreak years and its damage may be increased to 100%. The sunn pest causes harsh damage to wheat in the early and late season. Damage of early instars nymphs is not serious. The late nymphal stage and newly emerged adults are the most important stages in its life cycle. Adults start intense feeding on grains. The other damage is the chemicals that injects into the grain that demolishes the gluten and diminishes the baking quality of the flour (Brown and Erlap, 1962; Paulian and Popov, 1980; Popov *et al.*, 1996; Moore, 1998; Hariri *et al.*, 2000). Neonicotinoids are a wide group of insecticides. In mode of action and selective effect on invertebrates, neonicotinoids are similar to nicotine. Nicotinic acetylcholine receptors (nAChRs) is more common in invertebrates than in other animal groups. This systemic compounds are a set of nicotine-based

insecticides. Some of these compounds are imidacloprid, clothianidin, acetamiprid, thiacloprid, thiamethoxam, dinotefuran and nitenpyram (Abbink, 1991; Matsuda *et al.*, 2001; Halm *et al.*, 2006; Jones *et al.*, 2006).

The neonicotinoids used in this study were imidacloprid, thiamethoxam, acetamiprid and dinotefuran. Imidacloprid is a systemic chloronicotinyl insecticide. The systemic insecticide can move into the sap and distribute in the plant. Imidacloprid is used for control of sucking insects including hoppers, aphids, whiteflies, termites, sod and soil insects and some beetles on rice, cereal, maize, potatoes and vegetables. It was used as a seed treatment and soil treatment compound (Placke and Weber, 1993; Nauen *et al.*, 1998). Thiamethoxam, a new neonicotinoid, has stomach, contact and systemic activity and was used for controlling the pests of barley, cotton, sorghum, wheat, canola, and corn including aphids, whiteflies and leafhoppers (Yamamoto, 1996; Senn *et al.*, 1998; Maienfisch *et al.*, 1999; Mason *et al.*, 2000; Maienfisch *et al.*, 2001). Thiamethoxam has low toxicity to beneficial insects and mammals too. Because of its selective property, it was used as a seed treatment insecticide (Hofer and Brandl, 1999;

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Lawson *et al.*, 1999). Dinotefuran belongs to the neonicotinoids, as does imidacloprid (Moriya *et al.*, 1992). Dinotefuran [MTI-446, 1-methyl-2-nitro-3-(tetra-hydro-3-furylmethyl) guanidine], a new neonicotinoid insecticide, has high toxicity against a wide range of Hemiptera and low toxicity to mammals. Dinotefuran has the highest insecticidal activity against male of *Periplaneta americana* L. (Blattaria; Blattidae) compared to other neonicotinoids (Kodaka *et al.*, 1998; Kiriya and Nishimura, 2002). Next neonicotinoid, acetamiprid ((E)-N1-[(6-chloro-3-pyridyl) methyl]-N2-cyano-N1-methylacetamidine), is used for control of various orders of insects (Hemiptera, Thysanoptera, Coleoptera and Lepidoptera) on a broad range of plants, particularly vegetables and fruits (Roberts, 1999; Tomlin, 2000). In chemigation technology, application of agro-chemicals is improved via irrigation systems. Chemigation has ensured to develop stability of plant productivity (El-Gindy *et al.*, 2007). In agriculture, chemicals are used as fertilizers, pesticides, insecticides, fungicides, herbicides, nematocides, and growth regulators (Rolston *et al.*, 1986; Bar-Yosef, 1999). Chemigation has been a good way for control of nematodes and insects (Chalfant and Young, 1982; Csinos *et al.*, 1986).

The sunn pest is a major pest of cereal plants in Iran. In Iran, since 1950's, control of the sunn pest was based on chemical control specially DDT and organophosphate insecticides. Although neonicotinoid insecticides have a strong efficacy on sucking pests, any study doesn't exist in using these compounds on *E. integriceps* in Iran up to now. Also the authors didn't find any report on applying these compounds on the sunn pest via chemigation. The objective of this study was to investigate imidacloprid, thiamethoxam, acetamiprid and dinotefuran via chemigation and contact methods. In addition, we compared the efficacy of mentioned insecticides on the sunn pest with two methods.

2 MATERIALS AND METHODS

2.1 Insects and host plants

The overwintering adults of the sunn pest were collected in February of 2008 from overwintering locales in Kermanshah area in the west of Iran. The 3rd nymphal instars were collected through netting in the wheat and barley fields and were transferred to the plants in the plastic pots immediately. The insects were reared on wheat *Triticum aestivum* var. *Sardari* cultivated in plastic pots (7 cm in diameter

and 10 cm deep). The plants were maintained at $25 \pm 2^\circ\text{C}$ and $60\% \pm 5\%$ relative humidity (RH) in a growth chamber. Plants at 5 – 6-leaf-stage, 15 cm in height, were used for chemigation test.

2.2 Insecticides

The tested insecticides were thiametoxam (Actara® 240 SC, Syngenta Crop Protection, Switzerland), imidacloprid (Confidor® 350 SC, Bayer AG, Germany), dinotefuran (Starkle® 20 SG, Mitsui Chemicals, Japan) and acetamiprid (Mospilan® 20.4 SP, Nippon Soda, Japan)

2.3 Chemigation

In these studies, various concentrations (0.1, 0.5, 2, 8 and 20 mg/L a. i for thiametoxam and imidacloprid; 0.5, 2, 8, 15 and 20 mg/L a. i for dinotefuran; 4, 20, 40, 80 and 200 mg/L a. i for acetamiprid) were prepared in water, too. Two days before chemigation, the pots weren't irrigated. For each pot, 50 mL of the solution was applied. 96 h after treatments, the insects were released on the plants and 24 h after exposure, the results were recorded. Ten insects were released in each pot and each concentration was replicated 5 times. These tests were performed for overwintering adult insects and 3rd instar nymphs.

2.4 Contact bioassay

For contact bioassay, filter paper method was applied using Petri dishes (9 cm in diameter) to confine the insects. Filter paper disks (Whatman No. 1) were set to bottom of the Petri dishes. Four water-based concentrations (100, 500, 1 000 and 5 000 mg/L a. i.) of mentioned insecticides were prepared and water was used as control. Ten insects were placed in each Petri dish and each concentration was replicated 4 times. The insects were exposed to the treated papers for 24 h and then numbers of dead and alive insects were counted. These tests were performed for overwintering insects.

2.5 Data statistics and analysis

The data were analyzed in Probit analysis using SAS software (SAS Institute, 1997).

3 RESULTS

3.1 Chemigation on 3rd instar nymphs

Table 1 shows the LC_{50} values of tested insecticides on the 3rd nymphal instar of the sunn pest via chemigation. The results showed that all insecticides had effects on the 3rd instar nymphs. Toxicity of thiametoxam (0.51 mg/L) was higher than others (6.82 fold than imidacloprid, 9.52 fold than dinotefuran and 164.47 fold than acetamiprid). Toxicity of imidacloprid and dinotefuran was high too

(LC_{50} : imidacloprid = 3.48, dinotefuran = 4.86).

3.2 Chemigation on adults

LC_{50} confidence limit (95%) and regression slope after 24 h than exposure of neonicotinoids on adults of the sunn pest through chemigation are shown in Table 2. Toxicity of tested neonicotinoids to adults was acceptable and the LC_{50} values were low.

Similar to results of bioassay on 3rd nymphs, thiametoxam was the most effective compared to others. Adulticidal effect of thiametoxam was 2.44 fold as high as imidacloprid, 3.19 fold as high as dinotefuran and 23.88 fold as high as acetamiprid. In addition, toxicity of acetamiprid was lower than the others.

Table 1 Toxicity of the neonicotinoids to 3rd nymphs of the sunn pest, *Eurygaster integriceps* Puton, through chemigation

	n ^a	df	LC_{50}^b (mg/L a. i.)	LC_{90}^b (mg/L a. i.)	Slope $\pm$ SE	Intercept $\pm$ SE	χ^2
Thiametoxam	200	2	0.51 (0.19–1.13)	3.82 (1.53–141.10)	1.47 $\pm$ 0.48	0.43 $\pm$ 0.24	1.30
Imidacloprid	250	3	3.48 (1.26–17.53)	88.35 (17.54–42 247)	0.91 $\pm$ 0.29	–0.49 $\pm$ 0.22	1.65
Dinotefuran	250	3	4.86 (1.60–16.63)	88.80 (22.20–11 441)	1.02 $\pm$ 0.36	–0.68 $\pm$ 0.30	1.13
Acetamiprid	200	2	83.88 (51.73–171.81)	316.83 (159.73–3 160)	2.22 $\pm$ 0.66	–4.27 $\pm$ 1.23	0.12

n^a: Number of subjects; ^b 95% lower and upper fiducially limits are shown in parenthesis. The same for Table 2.

Table 2 Toxicity of the neonicotinoids to overwintered adults of the sunn pest, *Eurygaster integriceps* Puton, through chemigation

	n ^a	df	LC_{50}^b (mg/L a. i.)	LC_{90}^b (mg/L a. i.)	Slope $\pm$ SE	Intercept $\pm$ SE	χ^2
Thiametoxam	200	2	2.68 (0.90–6.41)	26.59 (9.70–695.50)	1.29 $\pm$ 0.39	–0.55 $\pm$ 0.30	0.22
Imidacloprid	250	3	6.54 (2.86–18.90)	76.58 (23.77–6 808)	1.20 $\pm$ 0.38	–0.98 $\pm$ 0.34	1.20
Dinotefuran	200	2	8.56 (3.22–20.66)	58.59 (22.95–15 822)	1.53 $\pm$ 0.58	–1.43 $\pm$ 0.59	0.80
Acetamiprid	200	2	64 (36.50–124)	266 (132.88–3 240)	2.07 $\pm$ 0.64	–3.73 $\pm$ 1.16	0.75

3.3 Contact bioassay

For determining the concentrations for the main test, high doses were used in the primary tests. Results of the primary tests indicated that none of them had contact toxicity to adults of the sunn pest at 100, 500 and 1 000 mg/L. At these concentrations (100, 1 000 and 5 000 mg/L), the mortality was lower than 50%. At very high concentration (5 000 mg/L) mortality was increased extortionary (Table 3), hence authors didn't do further test on contact toxicity.

4 DISCUSSION

According to results, although effect of neonicotinoid insecticides were notable on *E. integriceps* via chemigation, their toxicity through contact wasn't good. This fact stated that neonicotinoids have good ingestion toxicity in comparison with contact toxicity. In contact way, it must influxes in cuticle and then affects on insects. Confidently the insect's stylet is the fastest way for importing toxin. The LC_{50} values against 3rd instars were lower than against adults. Toxicity of thiametoxam to nymphs was 5.25 times higher than that to adults. This event was observed in imidacloprid and dinotefuran. This shows that

Table 3 Contact toxicity of various neonicotinoids to overwintered adults of the sunn pest, *Eurygaster integriceps* Puton

Insecticide	Concentration (mg/L a. i.)	Number	Number of dead insects	Mortality (%)
Imidacloprid	100	40	4	10
	500	40	6	15
	1 000	40	8	20
	5 000	40	32	80
Thiamethoxam	100	40	10	25
	500	40	10	25
	1 000	40	14	35
	5 000	40	32	80
Dinotefuran	100	40	4	10
	500	40	6	14
	1 000	40	6	15
	5 000	40	14	35
Acetamiprid	100	40	4	10
	500	40	6	15
	1 000	40	6	15
	5 000	40	38	95
Control		40	2	5

efficacy of neonicotinoids on nymphal stages is more severe than adults, whereas this effect did not occur in acetamiprid and LC₅₀ value of acetamiprid for adult was low compared to nymphs. In this study, toxicity of acetamiprid to 3rd nymphs and adults was lower than other insecticides. Neonicotinoids are used for sucking pests, a few reports exist in their efficacy on the sunn pest. But all of this researches were limited to parochial areas. Ali *et al.* (2005) evaluated the effects of three neonicotinoids (thiametoxam, imidacloprid and dinotefuran) on nymphs and adults of a major sucking pest, *Bemisia tabaci* (Genn) in the field and observed that acetamiprid, diafenthiuron and imidacloprid affected on adults but efficacy of them on nymphs wasn't good. In other study, Nauen and Denholm (2005) reported that thiametoxam, imidacloprid and dinotefuran belong to subgroup N-nitroguanidines and have an N-NO₂ group in their structures. Iwasa *et al.* (2004) observed that insecticides which have N-NO₂ group are more toxic than others for *Apis mellifera* (Hym.: Apidae). On the other hand, compound with NC group (acetamiprid) was less toxic. Kocak and Babaroglu (2006) studied the effects of six insecticides (acetamiprid, chlorpyrifosethyl, lambda-cyhalothrin, monocrotophos, thiacloprid and zeta-cypermethrin) on overwintered adults of *E. integriceps* in the field and reported that toxicity of acetamiprid was lower than other insecticide. Results of current study and reported work by Kocak and Babaroglu (2006) showed that acetamiprid had no strong effect on *E. integriceps*.

In conclusion, although the used nicotinoid insecticides in this research (thiametoxam, imidacloprid, dinotefuran and acetamiprid) had no contact toxicity to 3rd nymphs and adults of the sunn pest, chemigation bioassay had high effect on all insecticides. Regarding the results and importance of the sunn pest in Iran, neonicotinoid application via chemigation or seed treatment, is a substantial method for its population control. Studies on other neocotinoids by two mentioned control methods in future can help to compare insecticides of this group and choice the best one for better control of the sunn pest.

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新烟碱类杀虫剂对麦扁盾蝽若虫和成虫的毒效

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摘要: 在伊朗, 麦扁盾蝽 *Eurygaster integriceps* 是小麦和大麦上的主要害虫。新烟碱类杀虫剂是一类具有较强活性的杀虫剂, 对刺吸式口器害虫具有良好的效果。本研究应用触杀和熏蒸两种生测方法测定了 4 种新烟碱类杀虫剂(噻虫嗪、吡虫啉、呋虫胺和啉虫咪)对麦扁盾蝽 3 龄若虫和成虫的毒效。触杀法生测结果显示, 各杀虫剂对麦扁盾蝽没有强烈的触杀活性, 但是在高浓度下(5 000 mg/L a. i.), 可见较高的死亡率。熏蒸法生测结果显示, 所有杀虫剂对麦扁盾蝽的若虫和成虫均有较好的毒性。结果提示应用熏蒸方法可能是治理这一重要害虫的新方法。

关键词: 麦扁盾蝽; 新烟碱类杀虫剂; 毒性; 触杀活性; 熏蒸; 刺吸式口器害虫

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